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Full Vehicle Simulation for Parallel Hybrid Vehicles

John A. MacBain, Ph.D., Delphi
Joseph J. Conover, Delphi
Aaron D. Brooker, NREL

DELPHI

NREL

Outline
Parallel Hybrid Simulation

- **Background**
- **Description of Full Vehicle Simulation**
- **Using the Simulation**
- **Hybrid Battery Sizing Sample Study**
  - **Problem Definition**
  - **Baseline Vehicle Results**
  - **Optimization Results**
- **Conclusion**

Background

- **Goal: Parallel hybrid vehicle simulation**
  - **Detailed electrical models**
  - **Full vehicle system context**

- **Approach: Co-simulate detailed Saber electric component models in the full vehicle system context of ADVISOR**
  - **Saber is often chosen for detailed electric component modeling**
  - **ADVISOR (ADvanced VehIcle SimulatOR), based in MATLAB/Simulink, is often chosen for modeling full vehicle systems**

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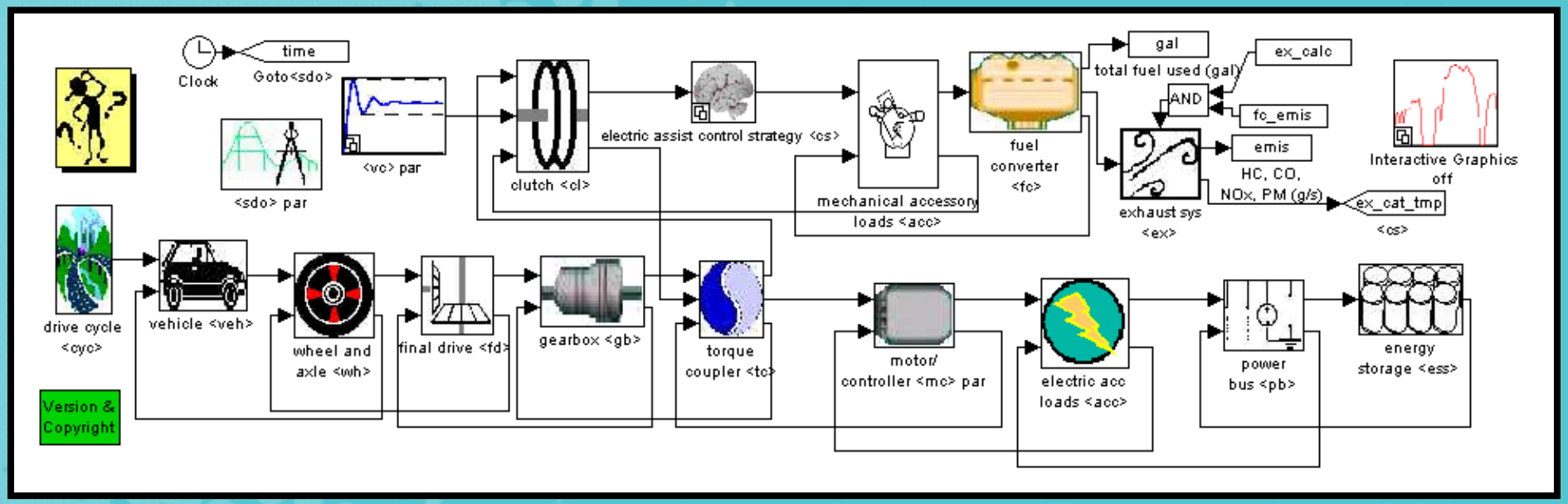
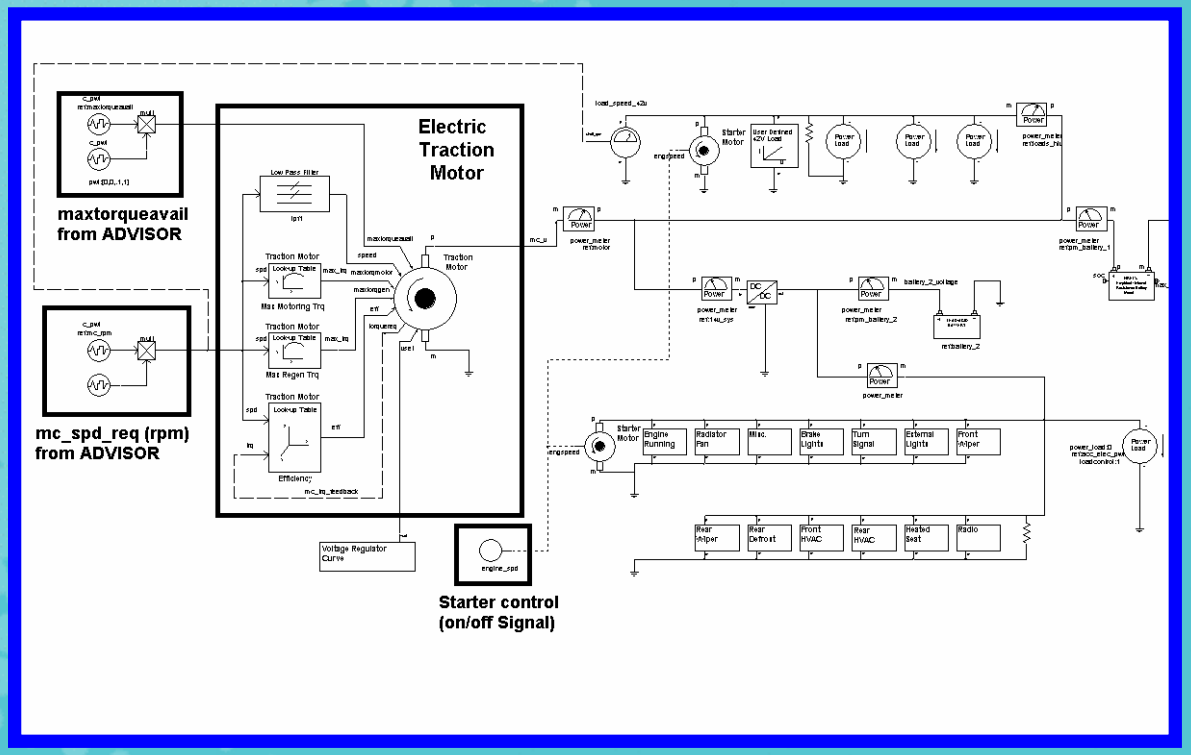
Description of Full Vehicle Simulation

- **ADVISOR models**
  - **Electrical solutions based upon power flow, not circuit equations**



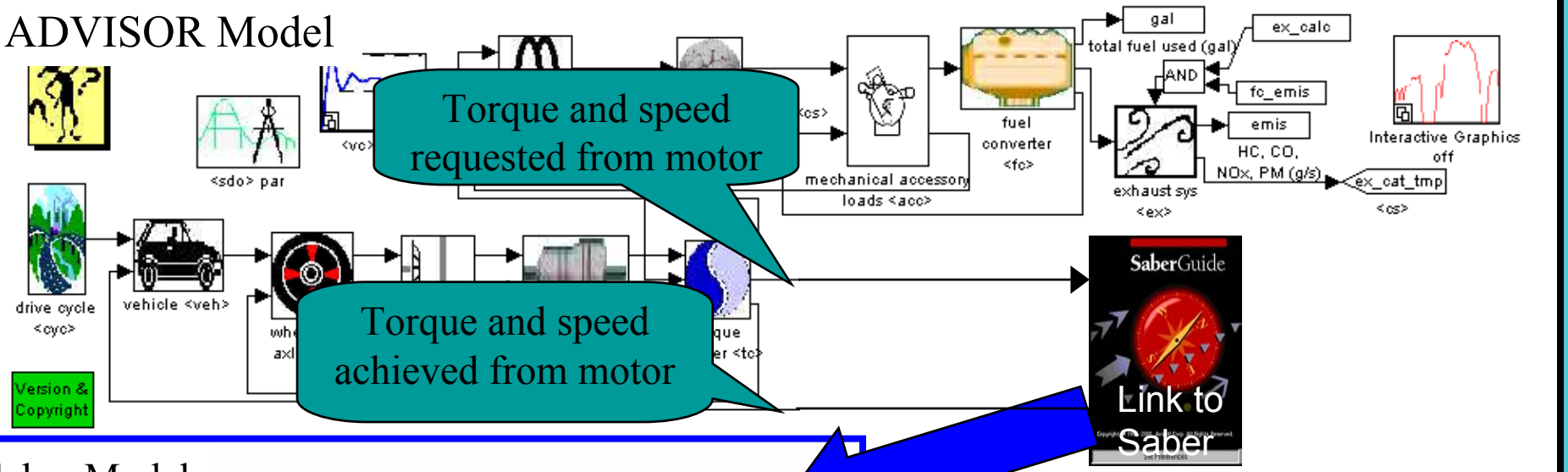
Description of Full Vehicle Simulation

- **Saber models**
  - **Sets up actual circuit equations**
  - **Solves circuit differential equations**
  - **Can also use empirical models**

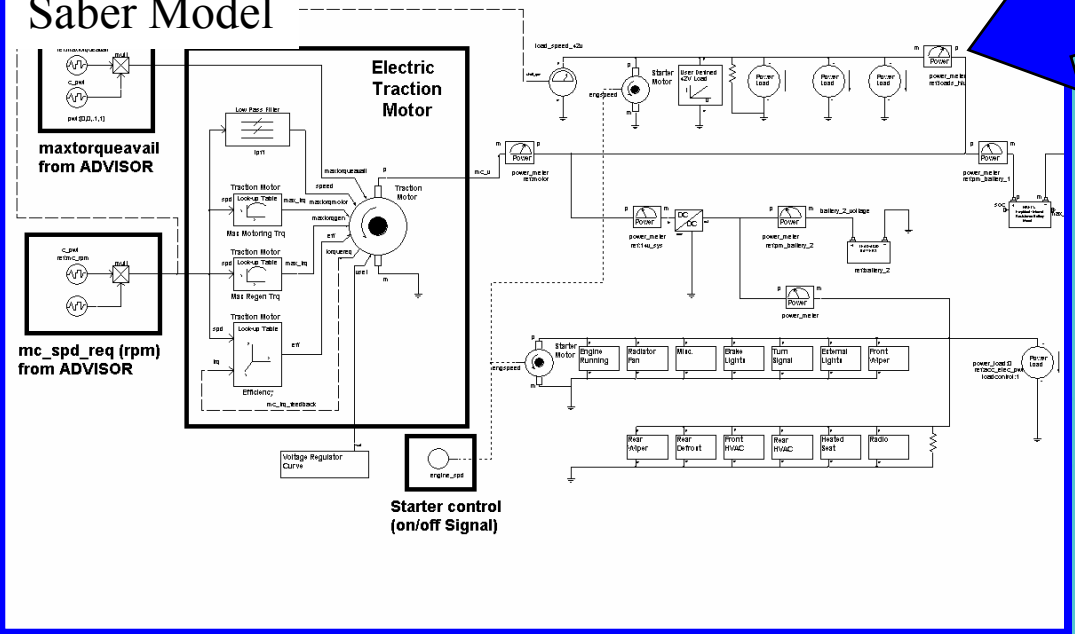


Description of Full Vehicle Simulation

ADVISOR Model

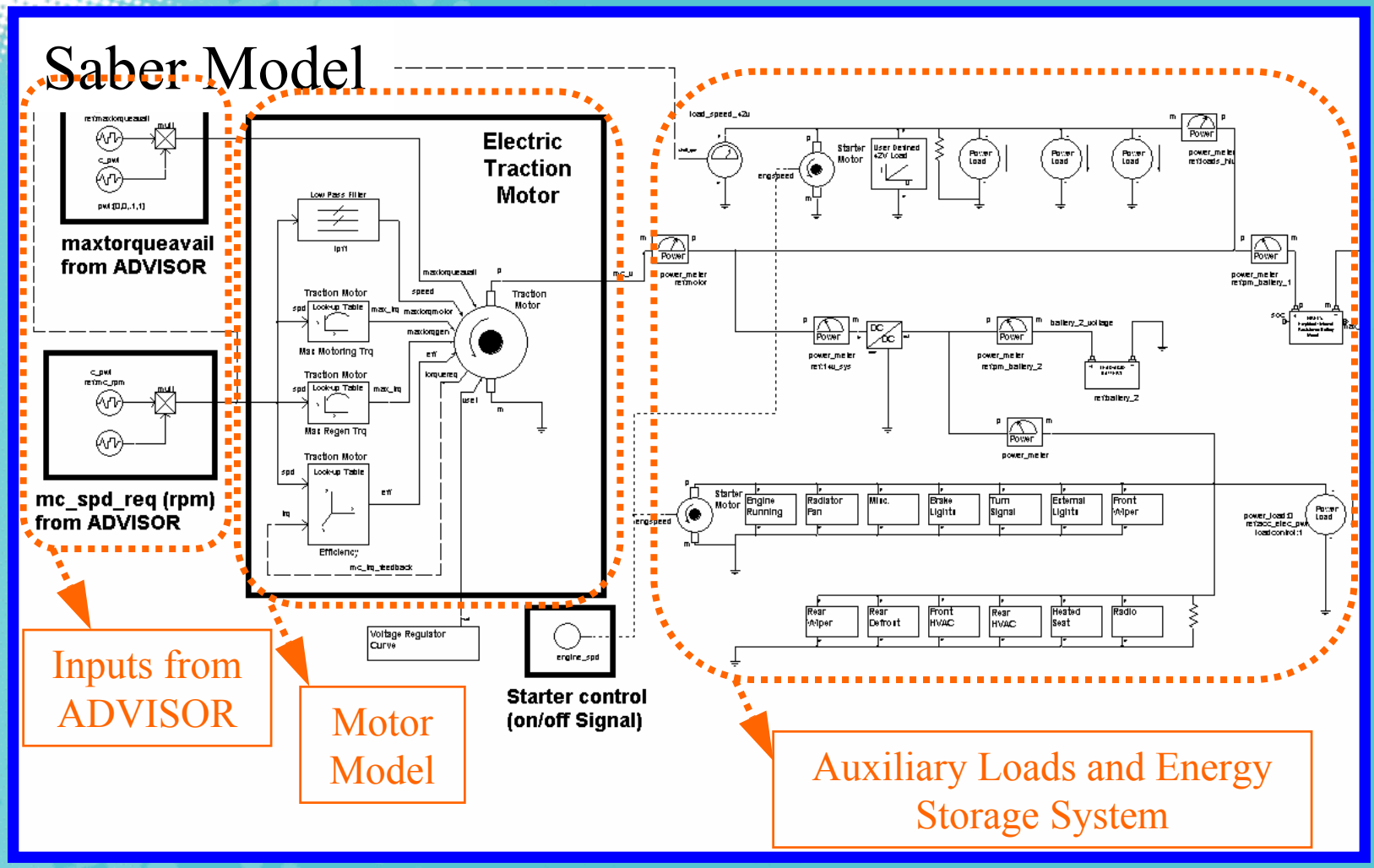


Saber Model



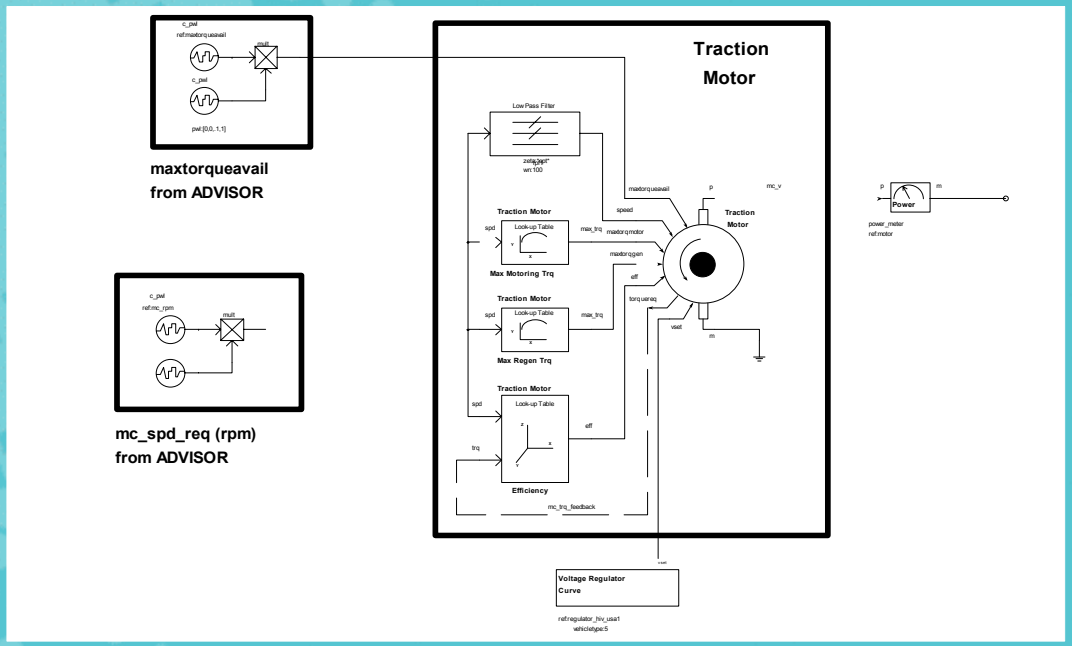
- **Replace ADVISOR electric models with more detailed Saber models**

Description of Full Vehicle Simulation

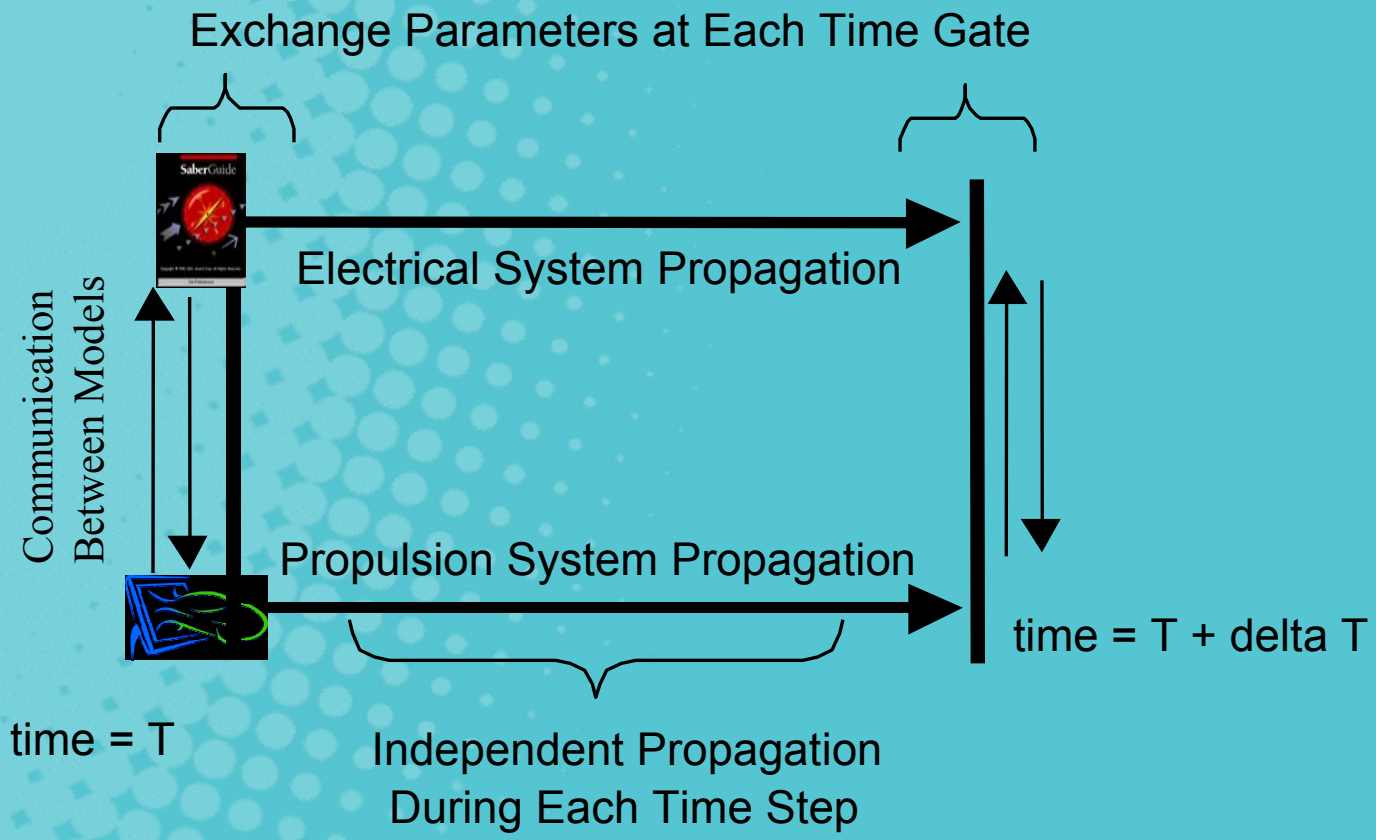


Description of Full Vehicle Simulation

- **Traction Motor Model for Hybrids**
  - **Driven by lookup table, permitting empirical replications of hardware performance**
  - **Calibrates from the same m-file used by ADVISOR battery models**



Description of Full Vehicle Simulation



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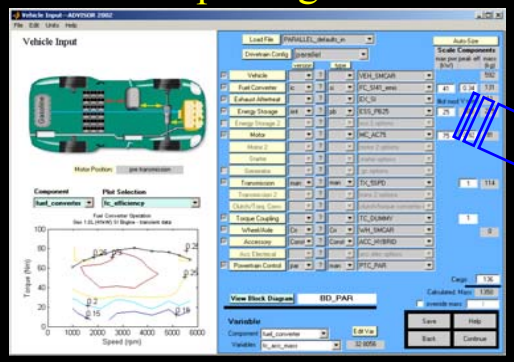
Using the Simulation

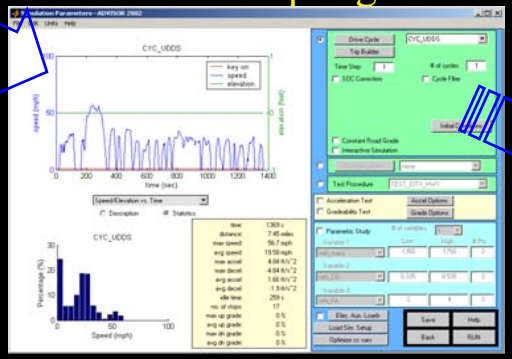
- **ADVISOR is Simulink model based. The model, however, runs in the background.**
- **Three main figures sit on top of the model to feed it data and receive results.**

Vehicle Input Figure



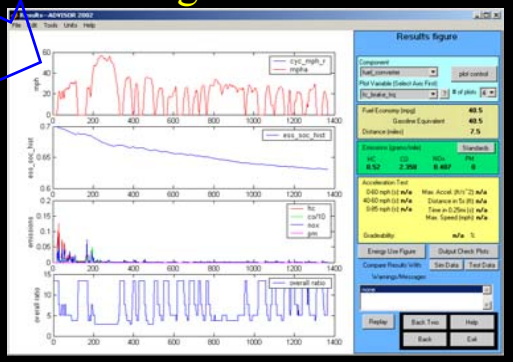
- Load Saber co-simulation model parameters
- Swap to the ADVISOR co-simulation model

Simulation Setup Figure



- Setup drive cycle
- Choose Auxiliary Loads

Results Figure



- View ADVISOR Results
- View Saber Results

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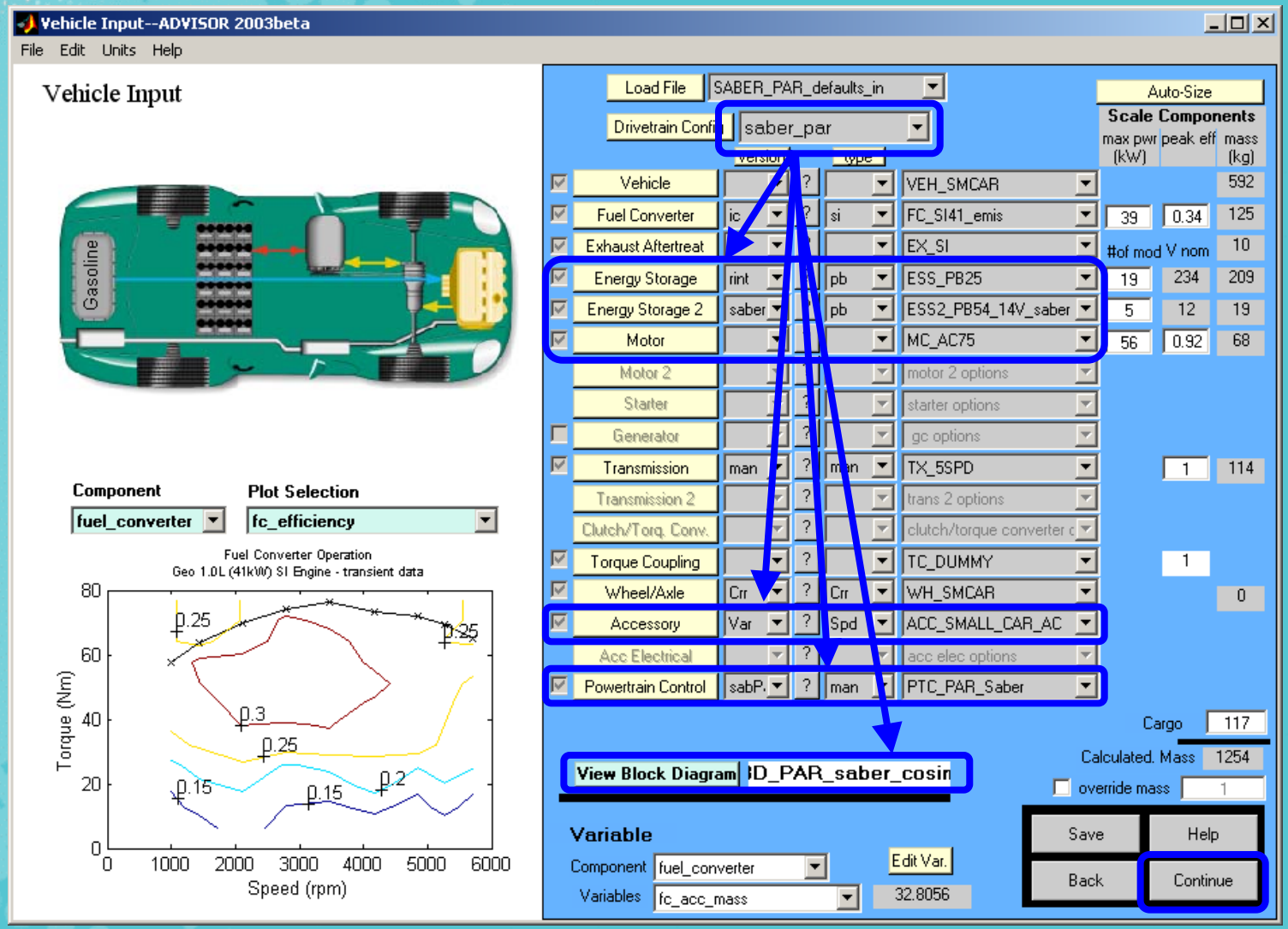
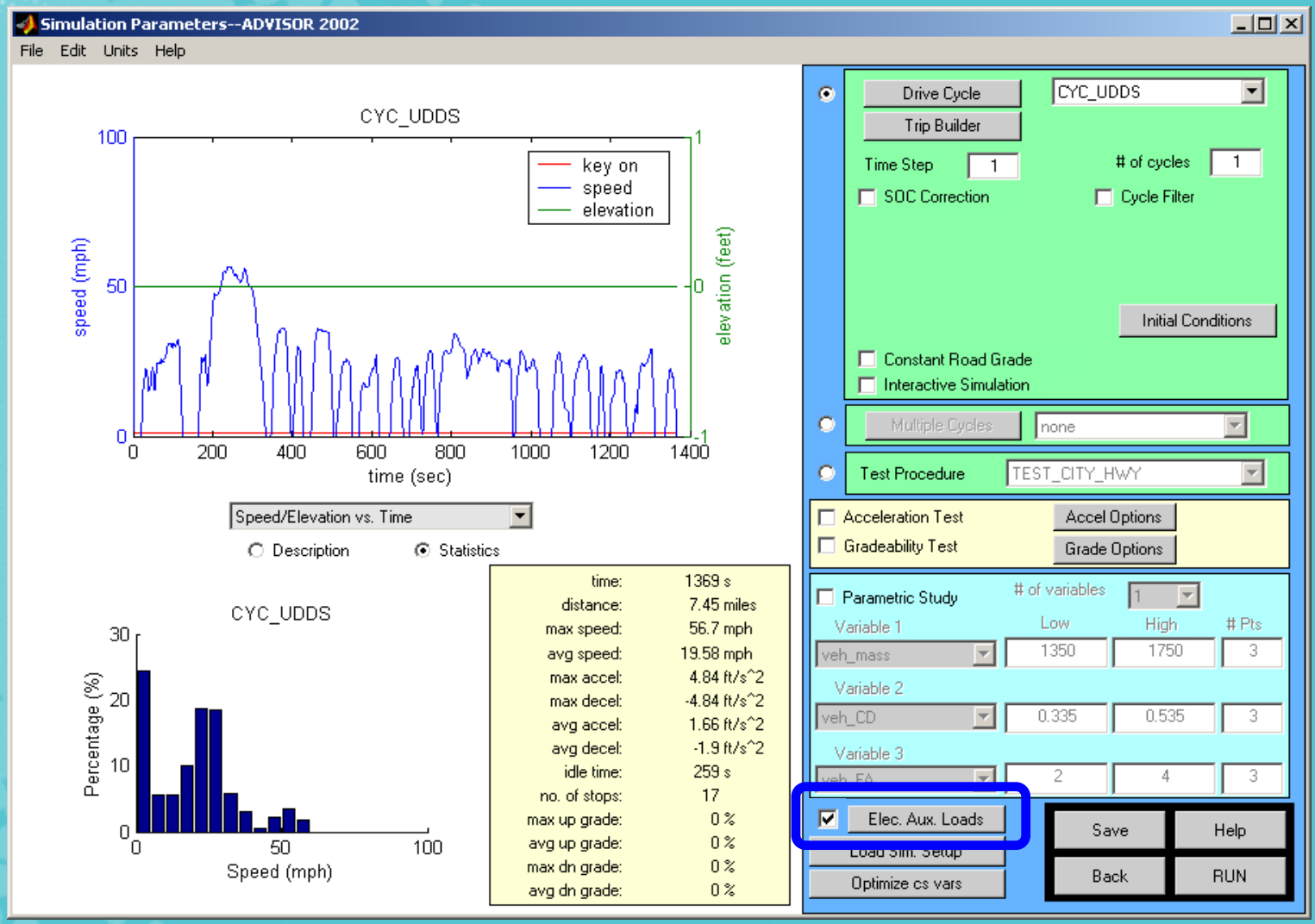
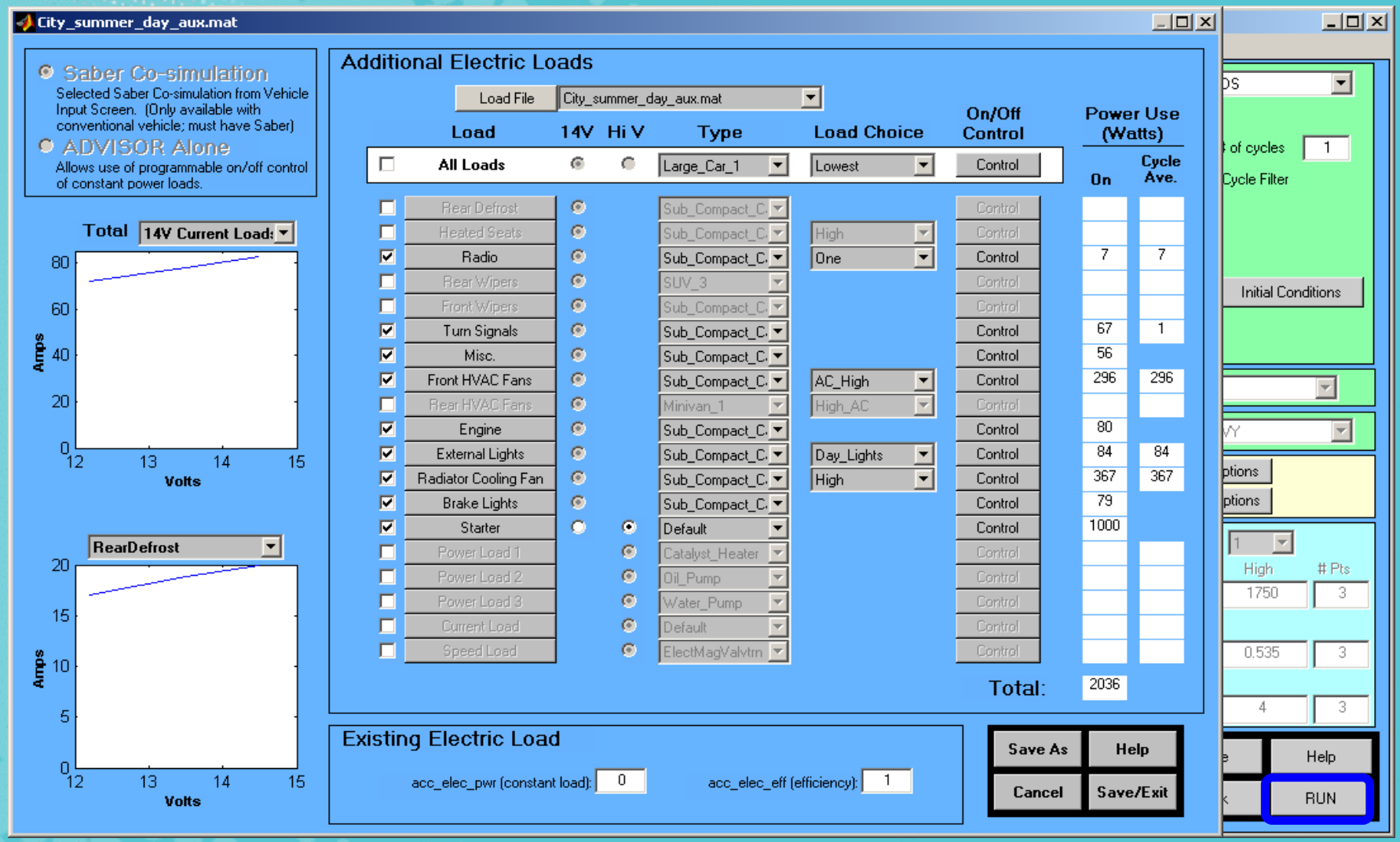
Using the Simulation Vehicle Input Figure



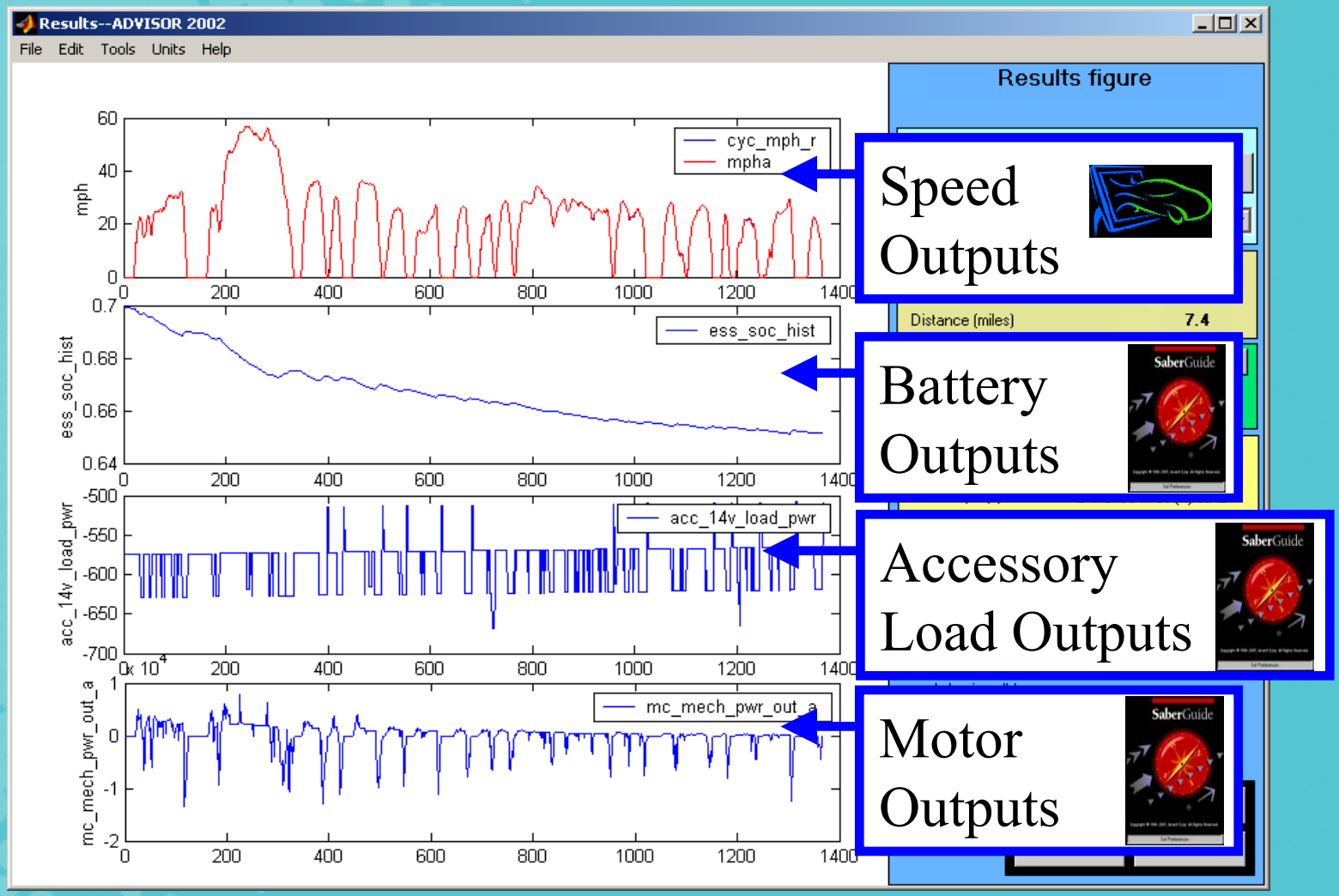
Using the Simulation Simulation Setup Figure



Using the Simulation Auxiliary Loads Figure



Using the Simulation Results Figure



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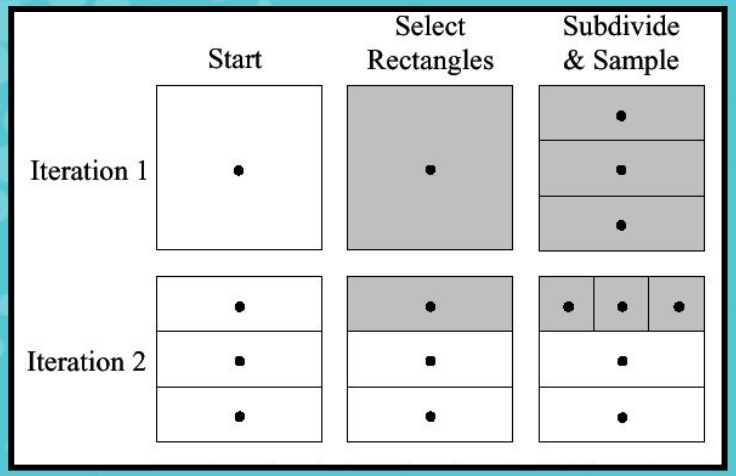
Hybrid Battery Sizing Sample Study Problem Definition

- ***Objective***
  - **Maximize fuel economy over urban dynamometer driving schedule (UDDS)**
- ***Constraints***
  - **Accelerate from 0 to 60 mph in 11 seconds**
  - **Stay within 2 mph of UDDS speed trace**
- ***Design variables***
  - **Engine size**
    - **Nominal engine size: 41 kW**
    - **Engine scale limits: 16.4 kW – 61.5 kW**
  - **Motor size**
    - **Nominal motor size: 75 kW**
    - **Motor scale limits: 7.5 – 37.5 kW**
  - **Discrete Battery Capacity**
    - **144 V NiMH**
    - **45 Ah, 60 Ah, 90 Ah**

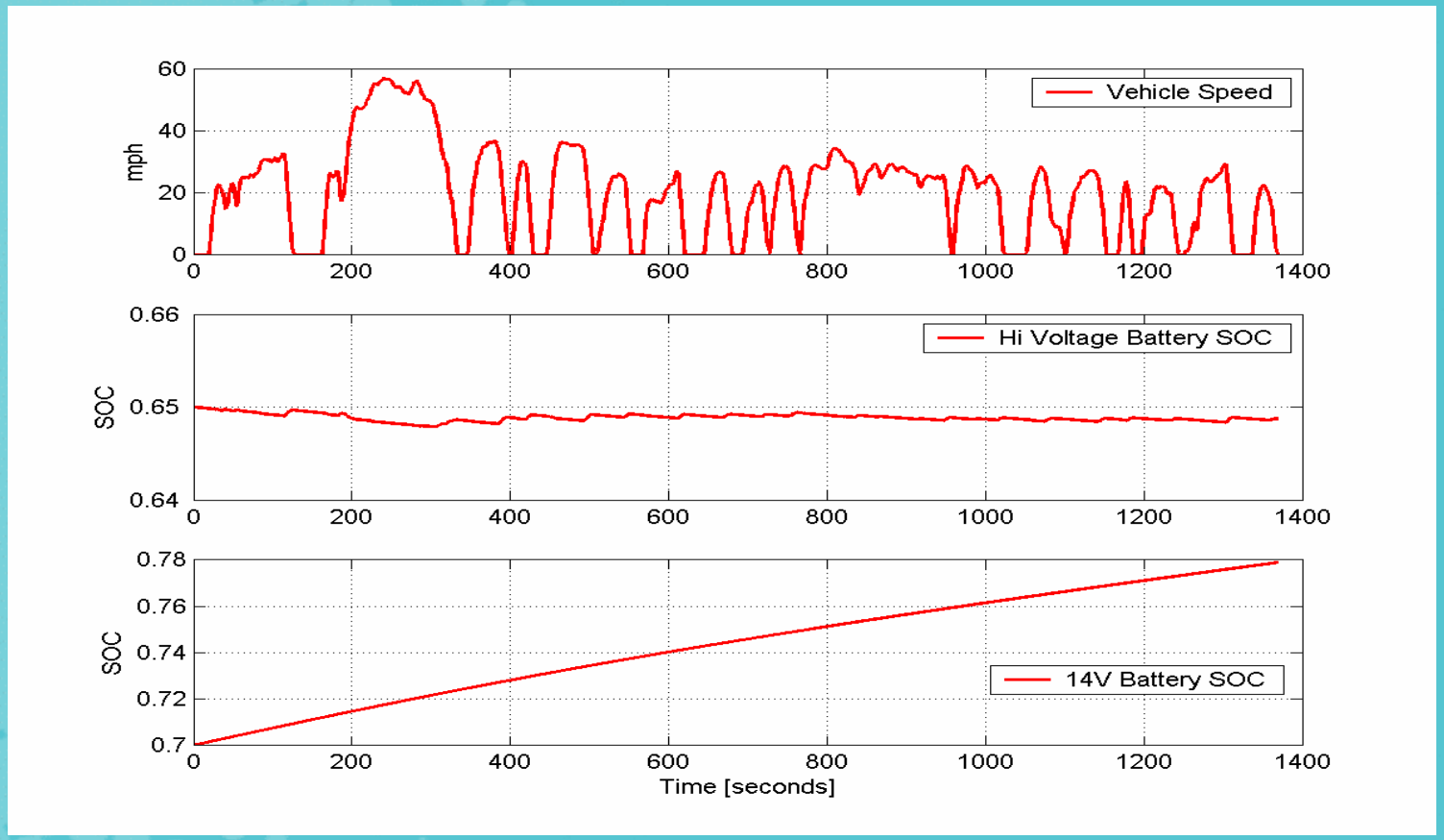
Hybrid Battery Sizing Sample Study Problem Definition

- ***Simplifying assumptions***
  - **Power assist parallel Saber co-simulation vehicle (small car)**
  - **Linear SOC balancing (computational efficiency)**
  - **DIRECT optimization routine**



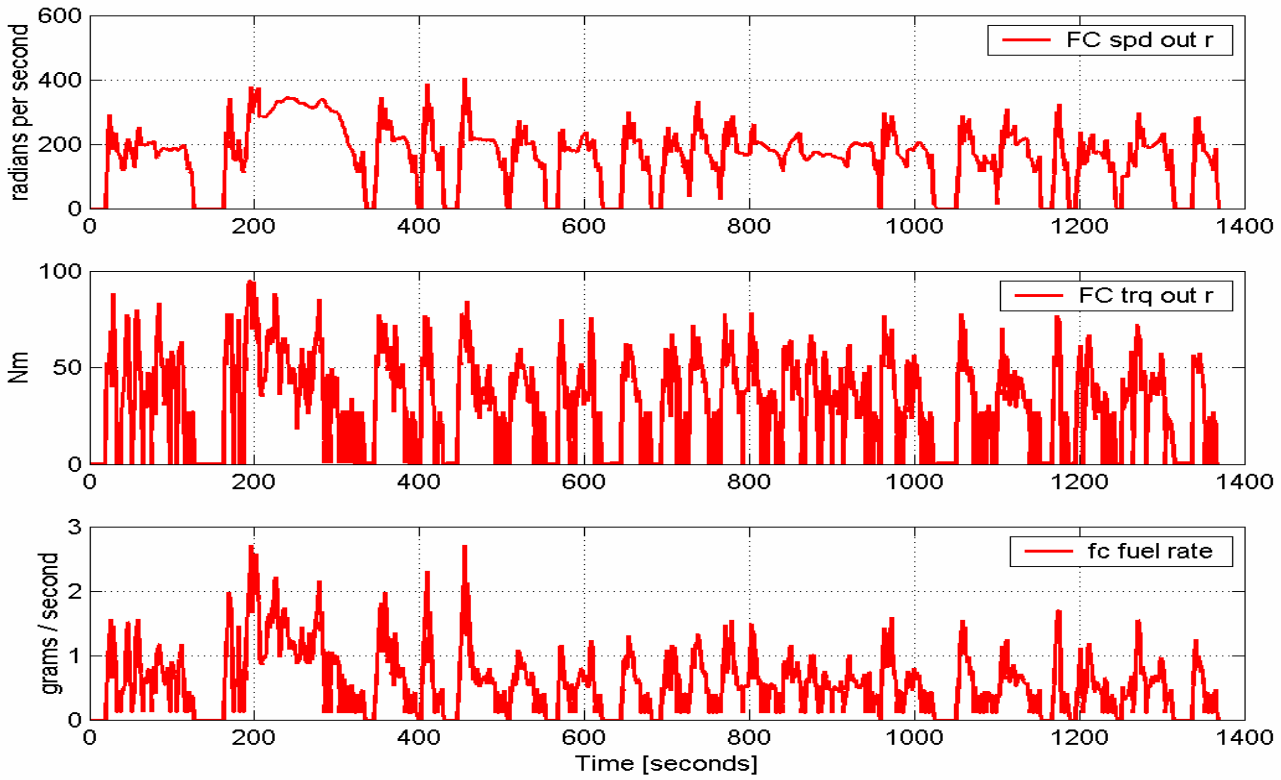
Hybrid Battery Sizing Sample Study Baseline Vehicle Results

Traces showing the drive cycle and the SOC for the batteries



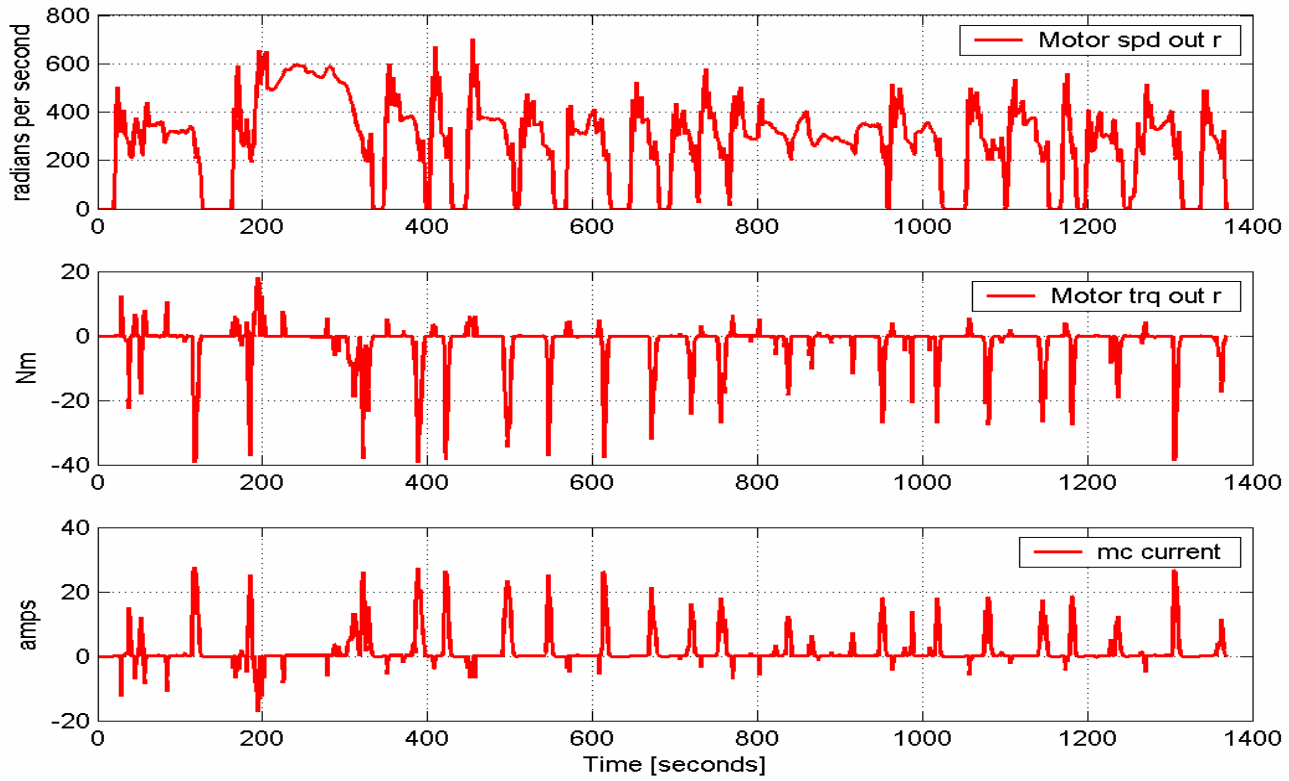
Hybrid Battery Sizing Sample Study Baseline Vehicle Results

Traces showing the engine activity



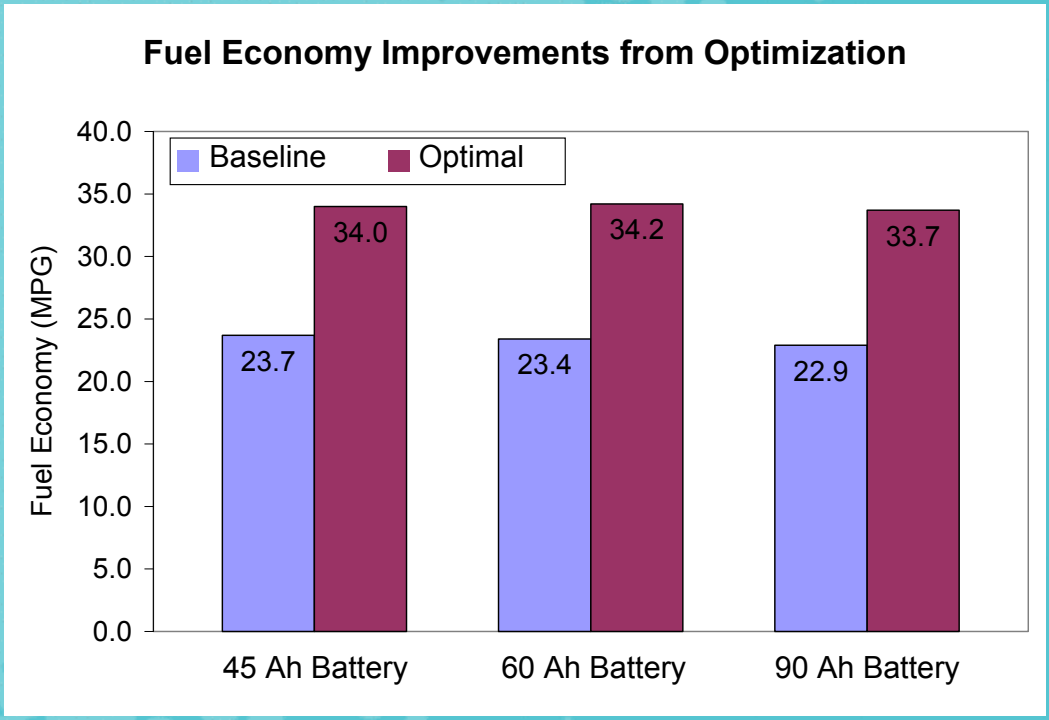
Hybrid Battery Sizing Sample Study
Baseline Vehicle Results

Traces showing the motor / generator activity



Hybrid Battery Sizing Sample Study Optimization Results

- **Optimization**
  - **Robust: Over 450 co-simulation runs**
  - **Automated**
  - **Integrated: Same optimization setup as running without co-simulation (all Saber values are passed from ADVISOR)**



Battery Type		Engine Size (kW)	Motor Size (kW)
45 Ah	Baseline	39	56
	Optimal	34	32
60 Ah	Baseline	39	56
	Optimal	32	36
90 Ah	Baseline	39	56
	Optimal	34	36

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Conclusions

- ADVISOR can now simulate a more detailed parallel electric hybrid by co-simulating with Saber
- Electrical component suppliers can now evaluate their Saber models in a full parallel hybrid vehicle context
- The co-simulation is completely integrated
  - Saber values are automatically sent in from ADVISOR
  - Automatically runs from the ADVISOR graphical user interface
- The co-simulation is robust
  - Capable of automated optimization routines